PROF. KIRCHHOFF.

GEHEIMRATH GUSTAV ROBERT KIRCHHOFF was born at Königsberg on the 12th of March, 1824. He commenced his professorial career at Berlin University as Privat Docent; became Extra-ordinary Professor in Breslau from 1850 to 1854, thereafter till 1874 Professor of Physics in Heidelberg, whence he was finally transferred (in a somewhat similar capacity) to Berlin. His health was seriously and permanently affected by an accident which befell him in Heidelberg many years ago, and he had been unable to lecture for some time before his death.

It is not easy, in a brief notice, to give an adequate idea of Kirchhoff's numerous and important contributions to physical science. Fortunately all his writings are easily accessible. Five years ago his collected papers (*Gesammelte Abhandlungen* von G. Kirchhoff, Leipzig, 1882) were published in a single volume. His lectures on Dynamics (*Vorlesungen über Mathematische Physik*, Leipzig, 1876) have reached at least a third edition; and his greatest work (*Untersuchungen über das Sonnenspectrum*, Berlin, 1862) was, almost immediately after its appearance, republished in an English translation (London, Macmillan). To these he has added, so far as we can discover, only three or four more recent papers; among which are, however, the following, published in the *Berlin Abhandlungen*:—

Über die Formänderung die ein fester elastischer Körper erfährt, wenn er magnetisch oder diëlectrisch polarisirt wird. (1884.)

A subsequent paper gives applications of the results (1884).

Additions to his paper (presently to be mentioned) on the Distribution of Electricity on two Influencing Spheres. (1885.)

While there are nowadays hundreds of men thoroughly qualified to work out, to its details, a problem already couched in symbols, there are but few who have the gift of putting an entirely new physical question into such a form. The names of Stokes, Thomson, and Clerk-Maxwell will at once occur to British readers as instances of men possessing such power in a marked degree. Kirchhoff had in this respect no superior in Germany, except his life-long friend and colleague v. Helmholtz.

His first published paper, *On electric conduction in a thin plate, and specially in a circular one* (Pogg. Ann. 1845), gives an instance. The extremely elegant results he obtained are now well known, and have of course (once the start was given, or the key-note struck) been widely extended from the point of view of the pure mathematicians. The simpler results of this investigation, it must be mentioned, were fully verified by the author's experimental tracing of the equipotential lines, and by his measurements of their differences of potential. A remark appended to this paper contains two simple but important theorems which enable us to solve, by a perfectly definite process, any problem concerning the distribution of currents in a network of wires. This application forms the subject of a paper of date 1847.

Kirchhoff published subsequently several very valuable papers on electrical questions, among which may be noted those on conduction in curved sheets, on Ohm's Law, on the distribution of electricity on two influencing spheres, on the discharge of the Leyden Jar, on the motion of electricity in submarine cables, &c. Among these is a short, but important, paper on the *Determination of the constant on which depends the Intensity of induced currents* (Pogg. 1849). This involves the absolute measurement of electric resistance in a definite wire. Kirchhoff was also the inventor of a valuable addition to the Wheatstone Bridge. To the above class of papers may be added two elaborate memoirs on Induced Magnetism (*Crelle*, 1853; *Pogg. Ergänzungsband*, 1870).

Another series of valuable investigations deals with the equilibrium and motion of elastic solids, especially in the form of plates, and of rods. The British reader will find part of the substance of these papers reproduced in Thomson and Tait's *Natural Philosophy*. There are among them careful experimental determinations of the value of Poisson's Ratio (that of the lateral contraction to the axial extension of a rod under traction) for different substances. These results fully bear out the conclusions of Stokes, who was the first to point out the fallacy involved in the statement that the ratio in question is *necessarily* 1/4.

Kirchhoff's *Lectures on Dynamics* are pretty well known in this country, so that we need not describe them in detail. Like the majority of his separate papers they are somewhat tough reading, but the labour of following them is certainly recompensed. They form rather a collection of short treatises on special branches of the subject, than a systematic digest of it. One of the most noteworthy features of the earlier chapters is the mode in which dynamical principles (*e.g.* the *Laws of Motion*) are introduced. While recognizing the great simplification in processes and in verbal expression which is made possible by the use of the term Force, Kirchhoff altogether objects to the introduction of the notion of *Cause*, as a step leading only to confusion and obscurity in many fundamental questions. In fact he roundly asserts that the introduction of systems of Forces renders it impossible to give a complete definition of Force. And this, he says, depends on the result of experience that in natural motions the separate forces are always more easily specified than is their resultant. He prefers to speak of the motions which are observed to take place, and by the help of these (with the fundamental conceptions of Time, Space, and Matter) to form the general dynamical equations. Once these are obtained, their application may be much facilitated by the introduction of the *Name* Force; and we may thus express in simple terms what it would otherwise be difficult to formulate in words. So long as the motion of a single particle of matter only is concerned we can, from proper data, investigate its velocity and its acceleration, as directed quantities of definite magnitude. Thus we proceed from Kepler's Laws to find the acceleration of a planet's motion. This is discovered to be directed towards the sun, and to be in magnitude inversely as the square of the distance. We may call it by the name Force if we please, but we are not to imagine it as an active agent. Something quite analogous appears in the equations of motion when we introduce the idea of Constraint. The mode in which the idea of Mass is introduced by Kirchhoff is peculiar. It is really equivalent to a proof (ultimately based on experiments) of Newton's *Third Law*. Once, however, it is introduced, the same species of reasoning (which differs but slightly from what we should call Kinematical) leads to the establishment of D'Alembert's and Hamilton's *Principles*, with the definition of the Potential Function, the establishment of Lagrange's Generalized Equations, and the proof of Conservation of Energy, &c. The observational and experimental warrant for this mode of treatment is, according to Kirchhoff, the fact that the components of acceleration are in general found to be functions of *position*. [Kirchhoff's view of Force has some resemblance to, but is not identical with either of, the views previously published by Peirce and by the writer.] This is the chief *peculiarity* of the book, and very different opinions may naturally be held as to its value, especially as regards the strange admixture of Kinematics and Dynamics.

Of the rest, however, all who have read it must speak in the highest terms. A great deal of very valuable and original matter, sometimes dealing with extremely recondite subjects, is to be found in almost every chapter. Among these we may specially mention the investigation

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of surface conditions in the distortion of an elastic solid, with the treatment of capillarity, of vortex-motion, and of discontinuous fluid motion (*Flüssigkeitsstrahlen*).

Besides these definite classes of papers, there is a number of noteworthy memoirs of a more miscellaneous character :—on important propositions in the Thermodynamics of solution and vaporization, on crystalline reflection and refraction, on the influence of heat conduction in a special case of propagation of sound, on the optical constants of Aragonite, and on the Thermal Conductivity of Iron.

Finally we have the series of papers on Radiation, partly mathematical partly experimental, which, in 1859 and 1860, produced such a profound impression in the world of science, and which culminated in the great work on the solar spectrum whose title is given above. The history of Spectrum Analysis has, from that date, been one of unbroken progress. Light from the most distant of visible bodies has been ascertained to convey a species of telegraphic message which, when we have learned to interpret it, gives us information alike of a chemical and of a purely physical character. We can analyze the atmosphere of a star, comet, or nebula, and tell (approximately at least) the temperature and pressure of the glowing gas. But, at the present time, the fact that such information is attainable is matter of common knowledge.

This is not an occasion on which we can speak of questions of priority, even though we might be specially attracted to them by finding v. Helmholtz and Sir W. Thomson publicly taking (in full knowledge of *all* the facts) almost absolutely antagonistic views. However these points may ultimately be settled, it is certain that Kirchhoff was (in 1859) entirely unaware of what Stokes and Balfour Stewart had previously done, and that he, with the powerful assistance of Bunsen, MADE what is now called Spectrum Analysis : Kirchhoff, by his elaborate comparison of the solar spectrum with the spectra of various elements, and by his artificial production of a new line whose *relative* darkness or brightness he could vary at pleasure ; Bunsen by his success in discovering by the aid of the prism two new metallic elements.

P. G. TAIT.

ON THE SIGNIFICATION OF THE POLAR GLOBULES.[1]

IT has long been known that the egg of some animals, after becoming mature and before undergoing its embryonic development, throws out certain bodies of globular form, which take no part in the embryonic development, but perish sooner or later. These polar globules have been found on the eggs of nearly all classes of animals, and it has been proved that they are real cells, composed of nucleus and cell-body.

Several theoretical opinions have been expressed in regard to their signification. Some naturalists believe them to be only a kind of excretion of the egg ; others even think them to be of no functional importance, and perceive in them only a remnant of some ancestral process, a recapitulation of some ancient part of the phylogenetic development.

Now it is true that, in many animals, structures occur without any physiological value, but it is also known that such structures—as, for instance, the hind-legs of whales—disappear more and more in the lapse of phylogenetic development. Furthermore, such rudimentary organs never disappear in all species and genera of a large group simultaneously, but in one genus or species they persist longer than in another. Thus, some whales possess certain of the bones of their hind-legs lying between the muscles of the trunk, whilst others have preserved only one bone of the pelvis. Now the polar globules might have been regarded as insignificant and rudimentary as long as they were only known in a few groups of the animal kingdom. But as their existence is now proved in nearly all classes of animals, and as they appear in all of them in the same manner, we are compelled to assume that they possess at least some physiological significance.

Mr. Sedgwick Minot and your illustrious Balfour made a great step forward in attempting—each independently of the other—to attribute a high importance to the expulsion of the polar globules. As you know, they suggested that the egg-cell was originally hermaphrodite, and that the polar globules were the male portion, which had to be thrown off. They based their idea upon the generally accepted view, according to which fecundation is the union of a specific male with a specific female substance. If this is true, then the fecundated ovum contains both these substances in equal quantities ; and the observations upon the segmentation of the egg lead further to the conclusion of E. Van Beneden, that all cells of the body contain these two substances, and that they are all hermaphrodite. The throwing out of polar globules was, according to these views, the means of preventing parthenogenesis, which must have occurred if the male substance had remained in the egg. This was Balfour's opinion, and he formulated the same with all precaution, putting it forward as a supposition, which might prove true or not. He himself even pointed out the way by which a decision could be obtained, in his statement, that, if his theory was true, polar globules would not be found in parthenogenetic eggs. Certainly, if polar globules represent the male substance, they cannot be thrown out in an egg that is not destined to be fertilized, and which therefore would not receive the male substance from another cell

Now, I have tried to decide this question by observing whether parthenogenetic eggs throw out polar globules or not, and I discovered several years ago that polar globules certainly exist in parthenogenetic eggs. I have found them in the summer eggs of Daphnidæ, and later, assisted by my pupil Mr. Ishikava, of Tokio, I have also found them in the parthenogenetic eggs of Cypridæ and of Rotatoria.

Now it is impossible that these polar globules can contain the male part of the egg. and the question arises, What other significance can be attributed to them ?

When I ascertained the facts which I have just described, I was not at the time aware of another fact that I am about to lay before you, and which seems to me to possess an important bearing upon the meaning of polar globules, and of sexual propagation in general. This fact is a very simple one : Parthenogenetic eggs throw out only *one* polar body, whilst sexual eggs throw out two of them.

The importance of this fact lies in the significance of the substance that is thrown out in the polar globules or polar cells. You know well that it is a true cell-division which leads to the formation of polar globules, and that the first polar cell takes away from the egg-cell one-half of the nuclear substance. You are also aware that the second polar cell again takes away half of the nuclear substance remaining in the egg. Hence in sexual eggs three-quarters of the nuclear substance originally contained in the egg-cell are taken away by the two polar cells. In parthenogenetic eggs only one polar cell is formed, and consequently only one-half of the original mass of nuclear substance is removed from the egg-cell.

Now you know that nuclear substance is a very important thing. The experiences and reflexions of the last ten years have led to the general conviction that nuclear substance is the part that controls the whole cell, and that the entire structure as well as the functions of the cell depend upon its minute structure. The nuclear substance is the idioplasma of the botanist Nägeli. Upon the molecular structure of it the form and function of every

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[1] Paper read by Prof. August Weismann before the British Association at Manchester.

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